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AQUATIC MACROINVERTEBRATES OF THE GRAND CALUMET RIVER

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ABSTRACT. The Grand Calumet River is potential habitat for a rich community of aquatic macroinvertebrates. Historical surveys of these organisms have been limited to post-industrialization of the Calumet Region; but because river habitats and conditions prior to industrialization have been described, past macroinvertebrate community composition can be inferred. In the past 20 years, several surveys have been conducted in the Grand Calumet that have focused on a limited area, but when these studies are amassed the information available covers much of the river. In this paper, the aquatic macroinvertebrate communities in the river are described, and options for restoration are discussed. Many of the macroinvertebrates present are indicators of high levels of pollution, but a few pollution-sensitive species have been found. There is evidence, however, that the sediment quality has improved since the 1960's, likely due to pollution controls that have been put into place. Restoration opportunities should consider the macroinvertebrate community and the potential to improve sediment habitat without damaging the community structure.

Keywords: Grand Calumet River, aquatic macroinvertebrates, pollution indicators

Macroinvertebrates—animals visible to the naked eye but that do not have backbones—are an extremely large, diverse group. Those with aquatic life stages are sensitive in varying degree to the physical and chemical characteristics of their aquatic environment, such as water temperature, flow rate, acidity, dissolved oxygen concentration, siltation rate, and types of pollution present. Aquatic macroinvertebrates can therefore be quite useful in indicating the status or quality of aquatic habitats. We describe the historical and present distribution of aquatic macroinvertebrates in the Grand Calumet River and Indiana Harbor Canal to ascertain present macroinvertebrate habitat quality and to explore sediment clean-up and restoration alternatives and their possible effects on macroinvertebrate communities.

HISTORICAL MACROINVERTEBRATE COMMUNITIES

The Grand Calumet River has undergone many changes in its history, as described in detail in other papers in this volume. The macroinvertebrate populations in the river have responded to these changes as various characteristics of their habitat were altered. Although there are no records for the macroinvertebrate communities prior to channelization and industrialization, enough is known about the characteristics of the river to estimate community composition. The Grand and Little Calumet Rivers once formed a slow-flowing, heavily-vegetated river that drained a vast wetland and emptied into Lake Michigan near present-day Marquette Park and the Grand Calumet Lagoons (Moore 1959). The rivers probably supported what Shelford (1977) calls a sluggish river community.

Shelford divided the sluggish river community into three "formations," the pelagic formation, the sand and silt bottom formation, and the zone of vegetation formation (1977). The pelagic, or open-water, formation is well-developed in larger rivers and was probably most important near the mouth of the Grand Calumet. This does not differ greatly from the pelagic formation of Lake Michigan, which includes copepods, cladocerans, roundworms, planarians, and leeches.

The sand and silt bottom formation includes mussels (*Anodonta grandis* and *Quadrula un-*

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dulata), snails (*Goniobasis livescens*), midge larvae, bryozoans (*Plumatella*), and occasional caddisfly larvae (*Hydropsyche*). Near the margin, a sandy bottom will include occasional snails (*Goniobasis*, *Pleurocera*, and *Campeloma*), midge larvae, occasional burrowing mayfly larvae, a number of mussels (*Unio gibbosus* and *Quadrula rubiginosa* being most characteristic), and occasionally a long-legged dragonfly larva (*Macromia taeniolata*). A silty bottom fauna includes the mussels *Quadrula undulata* and *Lampsilis siliquoidea*, the burrowing mayfly larva *Hexagenia*, midge larvae, segmented worms, sphaeriid clams, and the mud leech *Haemopis grandis*.

The zone of vegetation formation contains the water scorpion *Ranatra fusca*, the creeping water bug *Pelocoris femoratus*, the small water bug *Zaitha fluminea*, water boatman, the stillwater brook beetle *Elmis quadrinotatus*, several species of predaceous diving beetles, water scavenger beetles, mayfly larvae (*Caenis* and *Callibaetis*), the damselfly larva *Ischnura verticalis*, and dragonfly larvae (Aeschnidae and Libellulidae). It includes the pulmonate snails *Physa integra*, *Helisoma anceps*, and often species of *Lymnaea*. In addition, it includes the crayfish *Cambarus propinquus*, the amphipods *Hyalella azteca* and *Gammarus fasciatus*, viviparous snails (*Campeloma*), and an occasional mussel (*Anodonta grandis*). This zone is well-developed in the Grand Calumet River.

As the area became more populated and industrialized, the Grand Calumet River was degraded both physically and chemically. Canals and ditches were dug, wetlands were drained and filled, and stretches of river were dredged or moved, severely altering the hydrology of the area (Moore 1959). Industrial waste, sewage, and urban runoff increased the river's flow and contributed large amounts of solids, including organic matter and toxic chemicals. Between 1913–1937, many of the Chicago region's natural areas that Shelford studied were severely damaged, including a Grand Calumet site that was "destroyed by industrial waste" (Shelford 1977). Into the 1960's, most of the river was devoid of higher forms of aquatic life (FWPCA 1966). Since then, however, pollution controls have resulted in improvements in the river's water quality and aquatic communities. For example, while only 22–108 earthworms/m^2 were found in Indiana Harbor mouth sediments in the early 1960's, between 2400 and 500,000/m^2 were found in the same area in 1973 (CMSD 1980). Although aquatic earthworms are still the dominant taxon in the sediments of the Indiana Harbor and Canal, other less pollution-tolerant macroinvertebrates are now, at least, present (IDEM unpubl. data; Risatti & Ross 1989).

MACROINVERTEBRATE STUDIES

Information from five studies was combined to develop a fairly comprehensive database on Grand Calumet River macroinvertebrates. Following is a short description of the macroinvertebrate study methods in chronological order. See Fig. 1 for locations.

U.S. Geological Survey and Indiana Dunes National Lakeshore study.—Benthic (bottom) macroinvertebrate data from the Grand Calumet River Lagoons were collected by the U.S. Geological Survey from November 1978 to July 1980 and published by Hardy (1984). Organisms were collected on jumbo multi-plate artificial substrates placed in the East (NPS1) and West (NPS2) Lagoons for six weeks. One jumbo multi-plate substrate was placed in each of the two sites. The sites were sampled in November 1978, August 1979, and July 1980. All organisms were identified to genus, except the leeches (Hirudinea), earthworms (Oligochaeta), and water mites (Acari).

Indiana Department of Environmental Management study.—Benthic macroinvertebrate data from the Grand Calumet River and Indiana Harbor Canal were collected by the Indiana Department of Environmental Management from 1979–1988 (unpublished). The 1986–1988 data have been summarized by Bright (1988). Macroinvertebrates were collected with one to three multi-plate Hester-Dendy artificial substrate samplers per site. The samplers were generally left in the water from 6–8 weeks. Two samplers were collected from the East Branch of the Grand Calumet at Virginia Street (IDEM1) in 1987. Three samplers were collected from the East Branch at Bridge Street (IDEM2) in 1986, and two in both 1987 and 1988. Two samplers were collected from the East Branch at Cline Avenue (IDEM3) in both 1986 and 1988, and one in 1987. Three samplers were collected from the East Branch at Kennedy Avenue (IDEM4) in 1986 and two in 1988. Three samplers were collected from the West Branch of the Grand

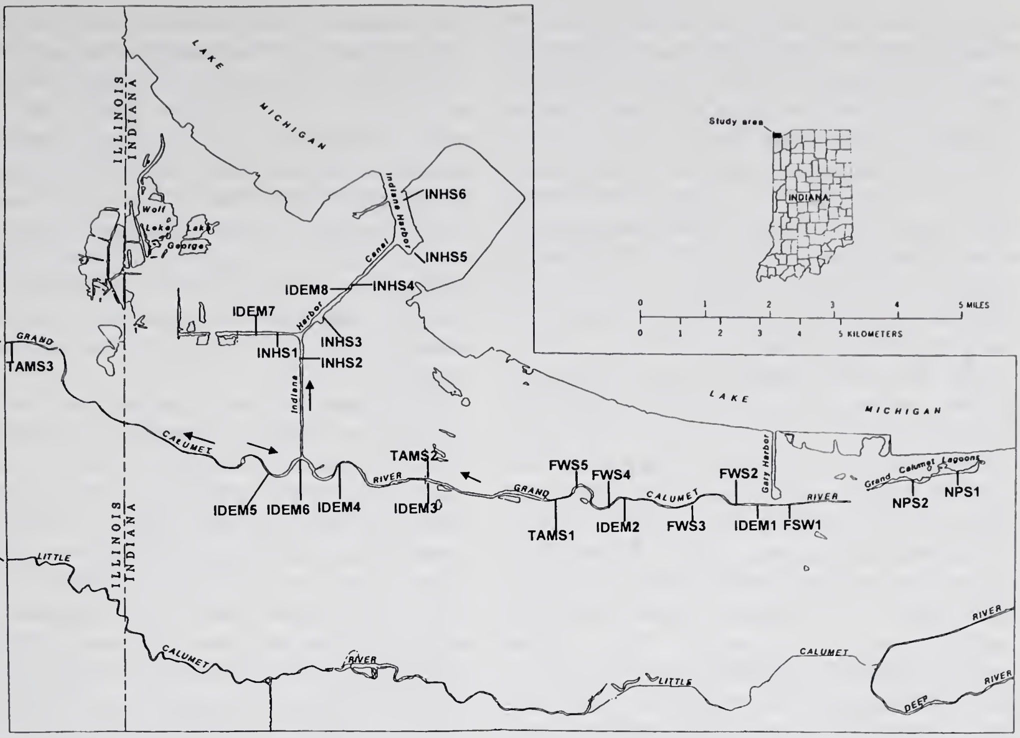

Figure 1.—Map of the study area with macroinvertebrate sampling sites identified. National Park Service sites from Hardy (1984); Indiana Department of Environmental Management sites from Bright (1988); Indiana Natural History Survey sites from Risatti & Ross (1989); TAMS sites from Mierzwa et al. (1991); and Fish amd Wildlife Service sites from Sobiech et al. (1994).

Calumet at Indianapolis Boulevard (IDEM5) in 1986. One sampler was collected from the mouth of the West Branch (IDEM6) in 1987 and two in 1988. Three samplers were collected from Lake George Canal at the railroad bridge (IDEM7) in 1986 and one in 1987. Three samplers were collected from Indiana Harbor Canal at Dickey Rd (IDEM8) in 1979, 1980, and 1981 and two in 1986, 1987, and 1988. Most organisms other than the aquatic earthworms were identified to genus (or species, if possible); however, the midges (Chironomidae) were usually not identified beyond family from every Hester-Dendy collected during a single sampling.

Illinois Natural History Survey study.—Benthic macroinvertebrate data from Indiana Harbor and Indiana Harbor Canal were collected by the Illinois Natural History Survey (INHS) on 3–4 May 1988 (Riatti & Ross 1989). Two petite Ponar grab samples were collected from each site, one for organism enumeration and identification, and one for determination of wet and dry biomass standing crop for the dominant taxa. Each grab sample was washed in a #30 mesh screen bucket and preserved in 10% buffered formalin. One site (INHS1) was located in Lake George Canal, just west of Indianapolis Boulevard. Three sites were located in Indiana Harbor Canal: INHS2, downstream of Columbus Drive; INHS3, downstream of Route 912; and INHS4, downstream of Dickey Road. Two sites were located in Indiana Harbor: INHS5, near the south end of the harbor; and INHS6, near the north end of the harbor. Sexually mature tubificid earthworms were identified to species level; other organisms were identified to family or genus level.

TAMS Consultants, Inc., study.—Benthic macroinvertebrate data from the Grand Calumet River were collected by TAMS Consultants, Inc. in 1990 and 1991 (Mierzwa et al. 1991). Three petite Ponar grab samples were collected from each site for each sampling period. Each sample was washed in a #30 mesh screen bucket and preserved in 10% buffered formalin. The East Branch was sampled at Route 12 (TAMS1) in July 1990, November 1990, and May 1991, and at Cline Avenue (TAMS2) in November 1990 and May 1991; the West Branch was sampled at Burnham Avenue (TAMS3) in November 1990, May 1991, and July 1991. Most organisms were identified to genus or species level, except the aquatic earthworms and midges, which were identified to family and subfamily. Numerical data were not published.

U.S. Fish and Wildlife Service study.—Benthic macroinvertebrate data from the East Branch of the Grand Calumet River were collected by the U.S. Fish and Wildlife Service in 1994 (Sobiech et al. 1994). Five multi-plate artificial substrate samplers consisting of five 5.8 cm diameter circular discs were placed at each site on 19 May 1994 and were retrieved on 29 June 1994. Qualitative (non-numerical) sampling was also performed. Only qualitative sampling was possible at the site upstream of Tennessee Street (FWS1). The East Branch was also sampled: FWS2, downstream of Broadway Avenue; FWS3, upstream of Interchange 13 entrance/exit ramps of I-90; FWS4, downstream of Bridge Street; and FWS5, at the Wabash railroad trestle. All organisms were identified to family, except the aquatic earthworms (Oligochaeta) and leeches (Hirudinea) to class and the scuds (Amphipoda), and crayfish (Decapoda) to order.

MACROINVERTEBRATES BY RIVER REACH

Lagoons reach.—This section includes the Grand Calumet River Lagoons east of USX (U.S. Steel Co.), and the sites NPS1 and NPS2 (Fig. 1). The Lagoons reach is different from the other reaches in that it is connected to the rest of the river by partially-constricted culverts. The most common taxa in this reach were the snail genus *Ferrissia* and the scud genus *Hyalella* in the East Lagoon and *Hyalella*, the midge genus *Glyptotendipes*, and the damselfly genus *Ischnura* in the West Lagoon (Hardy 1984) (Table 1). Although none of these taxa are considered particularly sensitive to pollution, the highest diversity of benthic invertebrates, including several sensitive taxa not found anywhere else, was found in this reach (Table 2).

Interestingly, the diversity indexes in the West Lagoon were lower than in the East Lagoon during wet periods—November 1978 and August 1979—and higher during the dry period—July 1980 (Hardy 1984). The suggested causes were lower seepage from the landfills north and south of the West Lagoon and greater organic enrichment in the East Lagoon. In addition, high ammonium concentrations in the West Lagoon (130–160× those common in surface water) corresponded with low diversity indexes, suggesting a possible source of stress on the West Lagoon community.

USX reach.—This reach includes the East Branch of the Grand Calumet River bordering the USX property. Sampling sites from east to west are: FWS1, IDEM1, FWS2, FWS3, IDEM2, FWS4, and FWS5 (Fig. 1). The most common taxa found in this reach were midges, the snail family Physidae, aquatic earthworms, and leeches (Table 1). In addition, the snail genus *Ferrissia* was common at IDEM2. At IDEM2, the only site at which midges were identified further than family level, the most common midge was *Cricotopus bicinctus*. Invertebrate Community Index (ICI) metric evaluation of the FWS study indicated that the invertebrate community of this reach was severely impaired (Sobiech et al. 1994). All sites received a total ICI score of 2 or lower and were classified as having very poor or poor invertebrate biotic integrity. The unbalanced trophic structure of the community, which was dominated by gathering collectors, also indicated degraded environmental conditions.

Gary Sanitary District reach.—This reach includes the East Branch of the Grand Calumet River from the USX property to Cline Avenue. Sampling sites from east to west include: TAMS1, TAMS2, and IDEM3 (Fig. 1). The most common taxa in this reach were aquatic earthworms, leeches, and the snail family Physidae, plus midges at IDEM3 (Table 1). The midges *Cricotopus* (unidentified) and *Cricotopus bicinctus* (possibly the same species) were common at IDEM3. The identification of damselflies and higher numbers of midges at IDEM3 is probably due to the use of Hester-Dendy artificial substrates at that site versus a petite Ponar at the TAMS sites. Mierzwa et al. (1991) found that, although the species richness, species diversity, and equitability of TAMS1 and TAMS2 were fair, the Macroinvertebrate Biotic Indices (MBIs) were quite poor, indicating pollution stress. In addition, the investigators noted a strong petroleum and sulfur odor and an anoxic appearance of the sediments.

DuPont reach.—This section includes the East Branch of the Grand Calumet River from Cline Avenue to the Indiana Harbor Canal. Sampling sites from east to west include: TAMS2, IDEM3, and IDEM4 (Fig. 1). Note that TAMS2 and IDEM3 are also included in the Gary Sanitary District Reach and are listed under that reach in Fig. 1. The most common taxa found in the DuPont Reach were aquatic earthworms, leeches, and the snail family Physidae, plus midges at IDEM3 and IDEM4 (Table 1). The midges *Cricotopus* (unidentified) and *Cricotopus bicinctus* (possibly the same species) were common at IDEM3. The identification of damselflies and higher numbers of midges at the IDEM sites is probably due to the use of Hester-Dendy artificial substrates at those sites versus a petite Ponar at TAMS2. Mierzwa et al. (1991) found that, although the species richness, species diversity, and equitability of TAMS2 were fair, the Macroinvertebrate Biotic Index (MBI) was quite poor, indicating pollution stress. In addition, the investigators noted a strong petroleum and sulfur odor and an anoxic appearance of the sediments.

Far West reach.—This reach includes the West Branch of the Grand Calumet River from the junction with the Little Calumet River (in Illinois) east to the Illinois/Indiana state line, and the site TAMS3 (Fig. 1). Only two taxa were identified at this site—the aquatic earthworm family Lumbriculidae and midge subfamily Chironominae (Table 1). Mierzwa et al. (1991) found this site to have very poor macroinvertebrate habitat, as indicated by its consistently low species richness, diversity, and equitability, and high (low quality) MBI.

Culverts reach.—This reach includes the West Branch of the Grand Calumet River from the Illinois/Indiana state line east to Columbia Avenue. None of the sampling sites are found within this reach. However, due to industrial and municipal impacts on sediment and water quality in the area, it is unlikely that the macroinvertebrate habitat is better than that in the Roxanna Marsh reach.

Hammond Sanitary District reach.—This reach includes the West Branch of the Grand Calumet River from Columbia Avenue in the west to the Hammond/East Chicago boundary. None of the sampling sites are found within this reach. However, due to industrial and municipal impacts on sediment and water quality in the area, it is unlikely that the macroinvertebrate habitat is better than that in the Roxanna Marsh reach.

Roxanna Marsh reach.—This section includes the West Branch of the Grand Calumet River from the Hammond/East Chicago boundary east to Indianapolis Boulevard, and sampling site IDEM5 (Fig. 1). The most common taxa found were the snail genus *Physa*, the midge *Parachironomus abortivus*, and the midge *Chironomus decorus* (Table 1). All of these are quite pollution-tolerant (Table 2), suggesting very poor habitat. There is a hydrologic divide at the western end of this reach, so some of the water flows west to join the Little Calumet River and some flows east to Lake Michigan via the Indiana Harbor Canal.

East Chicago Sanitary District reach.—This section includes the West Branch of the Grand Calumet River from Indianapolis Boulevard to the Indiana Harbor Canal, and sampling site IDEM6 (Fig. 1). The most common taxa found were the aquatic earthworms and crane flies (Tipulidae) (Table 1). Since crane fly larvae are considered only slightly pollution-tolerant (Table 2), this site may have somewhat better macroinvertebrate habitat than most. However, although crane fly larvae were the majority of the organisms collected in 1987, earthworms were quite dominant in 1988 (IDEM unpubl. data), suggesting very poor habitat.

Canal reach.—This section is the portion of the Indiana Harbor Canal from the Grand Calumet River north to Columbus Drive. None of the sampling sites are found within this reach. However, it is unlikely that the macroinvertebrate habitat is better than that in the Roxanna Marsh, East Chicago Sanitary District, and DuPont reaches, which precede it in water flow.

Lake George reach.—This section is the western portion of Lake George Canal, ending approximately 330 m west of Indianapolis Boulevard, and it includes the site IDEM7 (Fig. 1). The most common taxa found were bryozoans (Bryozoa), aquatic earthworms, the snail genus *Physa*, and *Hydra* (Table 1). Most of these are highly pollution-tolerant (Table

Table 1.—Macroinvertebrate taxa identified from the various river sections (reaches). Indiana Dunes National Lakeshore sites (NPS) are from Hardy (1984); Indiana Department of Environmental Management sites (IDEM) are from Bright (1988); Illinois Natural History Survey sites (INHS) are from Risatti & Ross (1989); TAMS Consultants, Inc. sites (TAMS) are from Mierzwa et al. (1991); and U.S. Fish and Wildlife Service sites (FWS) are from Sobiech et al. (1994). X = present, C = 20% or more of the total individuals found in any sample. * This beetle, recorded as "*Gyraulus*," is assumed to have been *Gyrinus*.

	Lagoons		USX Reach							Gary San. District			DuPont
Taxa	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Phylum Porifera													
Phylum Cnidaria													
Hydridae													
Hydra													
Phylum Platyhelminthes													
Turbellaria				X									
Phylum Nematoda											X		
Phylum Bryozoa													
Plumatella													
unidentified bryozoans													
Phylum Annelida													
Oligochaeta													
Lumbricidae										X	X		
Lumbriculidae										X	X		
Tubificidae													
Limnodrilus													
Limnodrilus cervix													
Limnodrilus hoffmeisteri													
Potamothrix vejdovskyi													
Quistadrilus multisetosus													
immature w/o capil. chaetae													
immature w/ capil. chaetae													
unidentified earthworms	X		X	C	X	X	C	C	X			C	C
Hirudinea													
Erpodellidae													
Dina microstoma?												X	
Dina parva										X			
Erpobdella punctata												X	X
Mooreobdella										X	X		
Mooreobdella fervida													X

Table 1.—Extended.

Taxa	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Phylum Porifera								C			
Phylum Cnidaria											
Hydridae										C	X
Hydra				C							
Phylum Platyhelminthes											
Turbellaria			X								
Phylum Nematoda											
Phylum Bryozoa											
Plumatella								C			
unidentified bryozoans				C				C			
Phylum Annelida											
Oligochaeta											
Lumbricidae											
Lumbriculidae	X										
Tubificidae											
Limnodrilus					X	X					X
Limnodrilus cervix					X	X			X		
Limnodrilus hoffmeisteri					C	C	C		C	C	C
Potamothrix vejdovskyi						X					
Quistadrilus multisetosus						X	C		X		
immature w/o capil. chaetae					C	C	C		X	C	X
immature w/ capil. chaetae						X					
unidentified earthworms		X	C	C				C			
Hirudinea											
Erpodellidae						X					
Dina microstoma?											
Dina parva											
Erpobdella punctata											
Mooreobdella											
Mooreobdella fervida											

Table 1.—Continued.

	Lagoons		USX Reach							Gary San. District			DuPont
Taxa	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Mooreobdella microstoma												X	X
Glossiphoniidae													
Helobdella											X		
Helobdella stagnalis							X					X	X
Placobdella										X	X		
unidentified leeches	X	X		X	X	C	X	C	X			C	C
leech cocoons													X
Phylum Mollusca													
Gastropoda													
Ancylidae													
Ferrissia	C						C						
Hydrobiidae											X		
Amnicola	X												
Lymnaeidae			X					X	X				
Lymnaea										X			
Physidae			C		C	X		C	X				
Aplexa										X			
Physa	X	X		X			C					C	X
Physella										X	X		
Planorbidae					X			X	X				
Gyraulus	X									X	X		
Helisoma												X	X
Planorbula	X												
Promenetus	X												
Promenetus?													
Valvatidae													
Valvata	X												
unidentified snails													
Pelecypoda													
Corbiculidae					X			X	X				

Table 1.—Continued Extended.

Taxa	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Mooreobdella microstoma		X									
Glossiphoniidae											
Helobdella											
Helobdella stagnalis		X		X				X			
Placobdella											
unidentified leeches			X	X				X			
leach cocoons		X		X							
Phylum Mollusca											
Gastropoda											
Ancylidae											
Ferrissia							X				
Hydrobiidae									C		
Amnicola											
Lymnaeidae											
Lymnaea											
Physidae											
Aplexa		C	X	C				X			
Physa											
Physella								X			
Planorbidae											
Gyraulus											
Helisoma				X				X			
Planorbula											
Promenetus											
Promenetus?								X			
Valvatidae											
Valvata											
unidentified snails								X			
Pelecypoda											
Corbiculidae											

Table 1.—Continued.

Taxa	Lagoons		USX Reach							Gary San. District			DuPont
	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Dreissenidae					X								
Sphaeriidae (unident.)												X	
Pisidium											X		
Sphaerium										X	X		
Phylum Arthropoda													
Branchiopoda													
"Cladocera"													
Amphipoda													
Hyalella	C	C		X									
unident. scuds									X				
Isopoda													
Caecidotea/Asellus	X	X											
Lirceus	X												
Decapoda													
Cambaridae						X							
Orconectes	X												
Arachnida													
Acari		X											
Insecta													
Ephemeroptera													
Baetidae													
Baetis		X											
Caenidae													
Caenis	X	X											
Heptageniidae													
Stenonema (*pulchellum* group)													
Odonata (Anisoptera)													
Aeshnidae			X			X		X	X				
Corduliidae													

Table 1.—Continued Extended.

Taxa	Far West TAMS3	Rox-anna IDEM5	E. Chic. IDEM6	L. George IDEM7	Federal Dredging Project Reach INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Dreissenidae											
Sphaeriidae (unident.)				X	X						X
Pisidium					X						
Sphaerium									X		
Phylum Arthropoda											
Branchiopoda											
"Cladocera"				X							
Amphipoda											
Hyalella											
unident. scuds											
Isopoda											
Caecidotea/Asellus											
Lirceus											
Decapoda											
Cambaridae											
Orconectes											
Arachnida											
Acari											
Insecta											
Ephemeroptera											
Baetidae											
Baetis								X			
Caenidae											
Caenis											
Heptageniidae											
Stenonema (*pulchellum* group)								X			
Odonata (Anisoptera)											
Aeshnidae											
Corduliidae											

Table 1.—Continued.

Taxa	Lagoons		USX Reach							Gary San. District			DuPont
	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Neurocordulia		X											
Tetragoneuria	X												
Libellulidae													
Erythemis													
Odonata (Zygoptera)													
Coenagrionidae						X		X	X				
Argia				X								X	X
Chromagrion	X	X											
Ischnura	X	C		X			X					X	
Lestidae									X				
unident. dameselflies							X					X	X
Trichoptera													
Hydropsychidae													
Cheumatopsyche													
Hydropsyche											X		
Hydropsyche orris?													
Hydropsyche simulans													
Hydropsyche simulans?													
Hydropsyche simulans pupae												X	
Hydroptilidae													
Neotrichia	X												
Orthotrichia	X												
Leptoceridae													
Anthripsodes		X											
Leptocerus		X											
Nectopsyche		X											
Oecetis		X											
Polycentropodidae													

Table 1.—Continued Extended.

Taxa	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Neurocordulia											
Tetragoneuria											
Libellulidae											
Erythemis				X							
Odonata (Zygoptera)											
Coenagrionidae											
Argia		X		X							
Chromagrion											
Ischnura		X		X				X			
Lestidae											
unident. dameselflies		X	X								
Trichoptera											
Hydropsychidae								X			
Cheumatopsyche			X					X			
Hydropsyche											
Hydropsyche orris?								X			
Hydropsyche simulans								X			
Hydropsyche simulans?								X			
Hydropsyche simulans pupae											
Hydroptilidae											
Neotrichia											
Orthotrichia											
Leptoceridae											
Anthripsodes											
Leptocerus											
Nectopsyche											
Oecetis											
Polycentropodidae											

Table 1.—Continued.

Taxa	Lagoons		USX Reach							Gary San. District			DuPont
	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Cyrnellus fraternus												X	
Neureclipsis													
Hemiptera													
Belostomatidae													
Lethocerus		X											
Corixidae									X				
Sigara	X												
Pleidae													
Plea		X											
Coleoptera													
Dysticidae													
Dytiscus				X									
Laccophilus		X											
Gyrinidae													
Dineutus		X											
Gyrinus?*													
Haliplidae													
Haliplus		X											
Diptera													
Ceratopogonidae													
Palpomyia	X	X											
unident. biting midges									X				
Chaoboridae													
Chaoborus							X						
Chironomidae													
Chironominae										X			
(Chironomini)													
Chironomus	X	X										X	X
Chironomus decorus													
Dicrotendipes/Limnochironomus	X	X											X

Table 1.—Continued Extended.

Taxa	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Cyrnellus fraternus				X							
Neureclipsis			X								
Hemiptera											
Belostomatidae											
Lethocerus											
Corixidae											
Sigara											
Pleidae											
Plea											
Coleoptera											
Dysticidae											
Dytiscus											
Laccophilus											
Gyrinidae											
Dineutus											
Gyrinus?*			X								
Haliplidae											
Haliplus											
Diptera											
Ceratopogonidae											
Palpomyia											
unident. biting midges			X								
Chaoboridae											
Chaoborus					X						
Chironomidae											
Chironominae	X										
(Chironomini)											
Chironomus			X								
Chironomus decorus		C									
Dicrotendipes/Limnochironomus								X			

Table 1.—Continued.

	Lagoons		USX Reach							Gary San. District			DuPont
Taxa	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Dicrotendipes nervosus													
Glyptotendipes	X	C										X	
Microtendipes	X												
Parachironomus													
Parachironomus abortivus												X	X
Phaenopsectra	X	X											
Polypedilum		X											
Polypedilum convictum							X					X	
Stenochironomus							X						
(Tanytarsini)													
Cladotanytarsus	X												
Rheotanytarsus													X
(Orthocladiinae)													
Cricotopus		X										C	X
Cricotopus bicinctus							C					C	X
Cricotopus intersectus												X	
Cricotopus sylvestris												X	X
Eukiefferiella		X											
Eukiefferiella discoloripes							X						
(Tanypodinae)													
Ablabesmyia		X											
Labrundinia		X											
Procladius sublettei													
Thienemannimyia group							X						
unident. midge larvae			X	X	C	C	C	X	C			X	C
unident. midge pupae							X					X	
Culicidae													
Tipulidae													
Empididae									X				
Stratiomyidae								X					
Syrphidae								X					

Table 1.—Continued Extended.

Taxa	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Dicrotendipes nervosus		X		X							
Glyptotendipes											
Microtendipes											
Parachironomus				X							
Parachironomus abortivus		C		X				X			
Phaenopsectra											
Polypedilum											
Polypedilum convictum											
Stenochironomus											
(Tanytarsini)											
Cladotanytarsus											
Rheotanytarsus				X				X			
(Orthocladiinae)											
Cricotopus				X							
Cricotopus bicinctus								X			
Cricotopus intersectus											
Cricotopus sylvestris								X			
Eukiefferiella											
Eukiefferiella discoloripes											
(Tanypodinae)											
Ablabesmyia											
Labrundinia											
Procladius sublettei		X									
Thienemannimyia group											
unident. midge larvae		C	X	X				X			
unident. midge pupae		X									
Culicidae			X								
Tipulidae			C								
Empididae											
Stratiomyidae											
Syrphidae											

2), indicating that the macroinvertebrate habitat is probably poor.

Federal Dredging Project reach.—The Federal Dredging Project reach, although not specifically addressed in this study, can provide additional information on Grand Calumet macroinvertebrate populations. This section includes the Indiana Harbor and Canal from Columbus Drive north to Lake Michigan and the eastern portion of Lake George Canal to approximately 330 m west of Indianapolis Boulevard. Sampling sites are: INHS1 in Lake George Canal; INHS2, INHS3, IDEM8, and INHS4 in Indiana Harbor Canal; and INHS5 nd INHS6 in Indiana Harbor (Fig. 1). The most common taxa found were aquatic earthworms, identified as the Family Tubificidae in the INHS sites, the snail family Hydrobiidae and hydras (Hydridae) at INHS5, and bryozoans (Bryozoa) at IDEM8 (Table 1).

Many taxa, such as the midges, mayflies (Ephemeroptera), caddisflies (Trichoptera), damselflies, and snails (other than Hydrobiidae), were identified at IDEM8 but not at the INHS sites. These differences likely stem from the different sampling methods used (Hester-Dendy *vs.* petite Ponar) and number of samples collected, rather than real differences in the communities. For example, both IDEM8 and INHS4 are in Indiana Harbor Canal near Dickey Road, yet at least 19 taxa were found at IDEM8 and only four at INHS4. The enumeration and identification data in the INHS study, however, were obtained from a single petite Ponar grab, whereas the IDEM data at this site are drawn from 15 Hester-Dendy artificial substrate collections over nine years. The IDEM data also show a general increase in richness and diversity from 1979–1988, with a peak in 1986 probably caused by historic highs in Lake Michigan water levels (Bright 1988). Although the invertebrate community in this reach is probably degraded, as indicated by the dominance of aquatic earthworms at every site, it may not be as poor as the INHS data suggest.

SPECIES LIST AND DESCRIPTIONS

Phylum Porifera (Sponges)

Members of the Phylum Porifera, the sponges, are the simplest animals. Of the more than 5000 species of sponges, the vast majority are marine, and only about 27 species occur in the fresh waters of the United States and Canada (Frost 1991). Freshwater sponges are common in unpolluted ponds, lakes, streams, and rivers, and they may be found attached to almost any stable submerged object (Pennak 1989). Sponges were found in Indiana Harbor Canal (Federal Dredging Project Reach) at IDEM8 in 1986 (Fig. 1 and Table 1). They were described as "abundant" on one of the two Hester-Dendy samplers retrieved from that location and were not identified any further. Sponges are generally sensitive to variations in environmental conditions, and several U.S. species have become extinct within the last 20–40 years, mainly due to pollution (Pennak 1989). However, sponges have been observed in a variety of polluted waters, their distribution depending upon the type and quantity of pollutant and individual species tolerances (Harrison 1974).

Phylum Cnidaria (Hydra)

Hydra spp. were found in 1987 and 1988 at three sites in the Federal Dredging Project reach—IDEM7, INHS5, and INHS6 (Fig. 1 and Table 1). They were identified as *Hydra* at IDEM7 and Hydridae at the other two sites. The class Hydrozoa has been rated quite tolerant of certain natural phenomena, such as high alkalinity, sulfate concentrations, sedimentation, and low stream gradients (USDA Forest Service 1989) (Table 2). Although hydras have been used as an indicator of moderately organically enriched streams and rivers in South Africa (Chutter 1972) (Table 2), a more recent study has found them to be characteristic of natural conditions (Patrick & Palavage 1994) (Table 2). Hydras are very sensitive to heavy metals and detergents (Slobodkin & Bossert 1991). It is likely that hydras inhabit other areas of the Grand Calumet River as well, since they are often either not collected or not well-preserved in routine collections due to their small size, soft bodies, and typically sessile habits.

Phylum Platyhelminthes Class Turbellaria (Flatworms)

Flatworms are common inhabitants of fresh waters, and more than 200 species occur in the fresh waters of North America (Kolasa 1991). Flatworms were identified at IDEM1 in the USX reach and IDEM6 in the East Chicago Sanitary District reach (Fig. 1 and Table 1). They were not identified to a lower level than class due to the inherent difficulty of recognizing the very small microturbellarians, but most likely they were planarians. Flatworms have been rated quite tolerant of certain natural phenomena and moderately tolerant of general pollution (USDA Forest Service 1989; Illinois EPA 1985) (Table 2). Planarians are generally intolerant of organic pollution, although some species have been observed in heavily polluted waters (Kenk 1974). They have been used as indicators of slightly enriched waters (Chutter 1972) (Table 2). Planarians are generally less sensitive to pesticides and herbicides than other invertebrates (Kenk 1974). It is likely that there are also flatworms in some of the other study sites that were not observed because of their small size (Kolasa 1991).

Phylum Nematoda (Roundworms)

Roundworms were found in the Gary Sanitary District and DuPont Reaches at TAMS2 (Fig. 1 and Table 1). They were not identified any further. Freshwater roundworms have been rated quite tolerant of certain natural phenomena and indicative of organically enriched or polluted waters (Table 2). However, they are not uniformly sensitive to pollutants (Poinar 1991), and a recent study did not rate them as being either pollution-tolerant or intolerant (Table 2). It is likely that roundworms also inhabit other areas, but their small size (most <1 cm in length) would make it easy for them to pass through the #30 sieves or to be unobserved during the separation of the macroinvertebrates from the rest of the samples.

Phylum Bryozoa/Ectoprocta & Endoprocta (Moss animals)

Bryozoans have been called "moss animals" because colonies of some common species can resemble a mat of moss. Approximately 4000 marine species of bryozoans have been described, and there are only about 50 freshwater species, including about 22 in the United States (Pennak 1989). Freshwater bryozoans attach to submerged surfaces, and will grow on aquatic vegetation and almost any solid, biologically-inactive material (Wood 1991). They survive in both still and running water, but are generally restricted to relatively warm water.

Bryozoans were identified in the Lake George reach at IDEM7 and the Federal Dredging Project reach at IDEM8 in 1986, 1987, and 1988 and were described as "abundant" or "dominant" in most samples (Fig. 1 and Table 1). Those collected from IDEM8 in 1986 on one of the Hester-Dendy samplers were identified as *Plumatella*. Freshwater bryozoans have various pollution tolerances, with *Fredericella sultana*, *Plumatella emarginata*, and *P. repens* being particularly tolerant of contamination from sewage and industrial wastes (Bushnell 1974). All species have been found most often in clean or mildly polluted habitats, however, so none should be considered indicators of pollution.

Phylum Annelida (Segmented worms)

The segmented worms include five classes that are represented in fresh waters. Of these, two—Oligochaeta and Hirudinea—were collected in the Grand Calumet River.

Class Oligochaeta (Aquatic earthworms).—Aquatic earthworms are smaller than their amphibious and terrestrial relatives, usually between 1–30 mm in length. The burrowing activity of aquatic earthworms can contribute greatly to sediment mixing and solute transport across the mud-water interface (Brinkhurst & Gelder 1991).

Aquatic earthworms were found at every site except NPS2 in the Lagoons reach (Fig. 1 and Table 1). They were identified simply as aquatic earthworms at the NPS, FWS, and IDEM sites. The Family Lumbricidae was collected at TAMS1 and 2 (Gary Sanitary District reach), and the Family Lumbriculidae was collected at TAMS1, 2, and 3 (Far West reach). The Family Tubificidae was identified at the INHS sites in the Federal Dredging Project reach as: *Limnodrilus*, *Limnodrilus cervix*, *Limnodrilus hoffmeisteri*, *Potamothrix vejdovskyi*, and *Quistadrilus multisetosus*. In addition, immature worms without capilliform chaetae were found at all six sites, and those with capilliform chaetae were found at INHS2.

Aquatic earthworms are generally considered quite tolerant of pollution and/or enrichment (Table 2). Species composition can be a valuable indicator, however, with a series of species groups inhabiting progressively more polluted stretches of rivers or more eutrophic lakes (Brinkhurst & Gelder 1991). In the Great Lakes, there are some species associations of Tubificidae characteristic of organically polluted bays and harbors: *Tubifex tubifex*, *Peloscolex multisetosus*, and several *Limnodrilus* species (dominated by *L. hoffmeisteri* and *T. tubifex*); *Aulodrilus*, *Potamothrix*, *Limnodrilus* and *Peloscolex ferox* are characteristic of eutrophic conditions; and *L. hoffmeisteri*, *T. tubifex*, and other species are characteristic of "clean" waters (Brinkhurst & Cook 1974).

Class Hirudinea (Leeches).—The leeches are predominantly freshwater organisms, with about 60 freshwater species known in the United States (Pennak 1989). They commonly inhabit ponds, marshes, lakes, and slow streams, particularly in the northern half of the country, and the same species may occur in a variety of environments. Leeches are represented in North America by four families, two of which were found in the Grand Calumet River: Erpobdellidae, which primarily prey upon macroinvertebrates and zooplankton; and Glossiphoniidae, which either prey upon macroinvertebrates or temporarily parasitize fish, turtles, amphibians, or water birds (Davies 1991).

Leeches were identified at all sites except FWS1 in the USX reach; TAMS3 in the Far West reach; and INHS1, 3, 4, 5, and 6 in the Federal Dredging Project reach (Fig. 1 and Table 1). No leeches were identified below class at the NPS or FWS sites. Those in the Family Erpobdellidae were identified as *Dina microstoma* (uncertain), *Dina parva*, *Erpobdella punctata*, *Mooreobdella*, *Mooreobdella fervida*, and *Mooreobdella microstoma*. The Family Glossiphoniidae was represented by *Helobdella*, *Helobdella stagnalis*, and *Placobdella*. Cocoons were identified at IDEM4, 5, and 7. It is possible that the lack of leeches found at the INHS sites was partially due to the limited sampling done (i.e., one petite Ponar grab per site).

Leeches are generally considered pollution tolerant (Table 2); however, different leech species have different tolerances to pollution, with only about a dozen in the United States and Canada commonly or occasionally associated with polluted water (Sawyer 1974). *Helobdella stagnalis* and *Erpobdella punctata* are by far the most important of these, but they are common and can only be considered indicator species in terms of unusually high densities. *Mooreobdella microstoma* and *Dina parva* are occasionally associated with disturbed environments. Patrick & Palavage (1994) rated *Dina parva*, *Erpobdella punctata*, and *Helobdella stagnalis* as pollution-tolerant species (Table 2).

Phylum Mollusca
(Mollusks)

Class Gastropoda (Snails).—Snails were found at every site except TAMS3 in the Far West reach and INHS1, 2, 3, 4, and 6 in the Federal Dredging Project reach (Fig. 1 and Table 1). The Family Ancylidae was identified to *Ferrissia*. The Family Hydrobiidae was identified to *Amnicola*. The Family Lymnaeidae was identified to *Lymnaea*. The Family Physidae was identified to *Aplexa*, *Physa*, and *Physella*. The Family Planorbidae was identified to *Gyraulus*, *Helisoma*, *Planorbula*, and *Promenetus*. The Family Valvatidae was identified to *Valvata*.

Most snails require high dissolved oxygen concentrations, so they are seldom found in severely polluted rivers or the deeper parts of lakes that become oxygen deficient (Pennak 1989). Other factors that can reduce the diversity of snails in a body of water are low pH values, heavy metals, pesticides, extreme temperatures, and organic pollution (Harman 1974). The pulmonates (Ancylidae, Lymnaeidae, Physidae, and Planorbidae) are more resistant to organic pollution. Of the snails found in these studies, *Valvata* and *Amnicola* are the least pollution tolerant (Table 2).

Class Pelecypoda (Bivalves).—Bivalves, including clams and mussels, live in almost all types of freshwater habitats but are particularly common in larger rivers (Pennak 1989). There are 266 species in North American fresh waters, including 227 in the Superfamily Unionacea, 37 in the Family Sphaeriidae (four introduced), and two additional exotics, *Corbicula fluminea* (Asiatic clam) and *Dreissena polymorpha* (zebra mussel) (McMahon 1991). The vast majority of freshwater bivalves feed by filtering suspended microscopic particles, such as organic detritus and plankton (Pennak

1989). Freshwater bivalves are hosts for various parasites, including flukes, roundworms, aquatic earthworm *Chaetogaster limnaei*, and water mites of the Family Unionicolidae.

Bivalves were identified at FWS2, 4, and 5 in the USX reach; TAMS1, TAMS2, and IDEM3 in the Gary Sanitary District and DuPont reaches; IDEM7 in the Lake George reach; and INHS1, 4, and 6 in the Federal Dredging Project reach (Fig. 1 and Table 1). Asiatic clams (Corbiculidae) were identified at FWS2, 4, and 5. Zebra mussels (Dreissenidae) were identified at FWS2. Sphaeriidae was identified to family at IDEM3, IDEM7, INHS1, and INHS6; *Pisidium* at TAMS2 and INHS1; and *Sphaerium* at TAMS1, TAMS2, and INHS4. No unionaceans were found.

Bivalves are adversely affected by various forms of pollution, including chemical wastes, asbestos, heavy metals, chlorine and paper mill effluents, urban wastewater effluents, and silt and acid discharges from mines (McMahon 1991). They have been rated both quite tolerant of certain natural phenomena and indicative of clean unpolluted waters (Table 2). Species diversity and density of unionaceans have declined greatly in North America in the last century, and many unionaceans are currently endangered (McMahon 1991). Many reasons have been postulated for this massive decline, including the freshwater pearling industry, extensive artificial impoundments, and channelization of drainage systems. *Corbicula* has been rated slightly tolerant of polluted conditions (Table 2). *Pisidium* and *Sphaerium* have been rated tolerant and somewhat tolerant of pollution (Table 2). Certain Sphaeriidae species, such as *Sphaerium transversum*, are tolerant of polluted, nearly septic conditions (Fuller 1974).

Phylum Arthropoda (Subphylum Crustacea)

Although only about 10% of the nearly 40,000 species of crustaceans occur in fresh waters, they are extremely important in many freshwater ecosystem processes (Covich & Thorp 1991).

Class Branchiopoda (Water fleas)

Water fleas, small (most < 1 mm in length) transparent animals, are widespread, living in all but the harshest freshwater habitats. Some water fleas are bottom dwellers (benthos), whereas others inhabit open water. Most water fleas are filter-feeders, eating a variety of small particles including bacteria, algae, ciliates, and small rotifers (Dodson & Frey 1991). They are an important food source for fish; in addition, they are eaten by hydras and immature and mature insects (Pennak 1989).

Water fleas were found at only one site—IDEM7 in the Lake George reach (Fig. 1 and Table 1). Two organisms were identified in 1986, and they were not identified to a lower taxonomic level. Water fleas have been rated quite tolerant of certain natural phenomena (Table 2). Pollution tolerances vary among species, but most (19 out of 22) of the water flea species identified in the Delaware and Neches Estuaries and the Flint River in New England were rated characteristic of natural conditions by Patrick & Palavage (1994).

Class Malacostraca

The class Malacostraca includes the superorders Pancarida (order Thermosbaenacea), Peracarida (orders Mysidacea, Amphipoda, and Isopoda), and Eucarida (order Decapoda) (Covich & Thorp 1991). Of these, amphipods (scuds), isopods (sow bugs), and decapods (crayfish and shrimp) were found in the Grand Calumet River.

Order Amphipoda (Scuds).—Scuds are found in unpolluted lakes, ponds, streams, brooks, springs, and subterranean waters (Pennak 1989). They are usually bottom species found only in shallow waters. Scuds are omnivorous, general scavengers, or detritus feeders and occasionally, filter feeders. Predators of scuds include fish, birds, aquatic insects, and amphibians, and parasites include tapeworms, flukes, roundworms, and Acanthocephala. In addition, algae and protozoans thrive on their external surfaces.

Scuds were found in both of the Grand Calumet Lagoons and in the USX reach (Fig. 1 and Table 1). They were identified simply as Amphipoda at FWS5, and to *Hyallela* (most likely *Hyallela azteca*) at NPS1, NPS2, and IDEM1. They were common at NPS1 and NPS2. Since scuds generally require high dissolved oxygen concentrations, they are usually limited to clean, cold waters (Covich & Thorp 1991). Also, they are especially sensitive to copper and a number of other heavy metals. Scuds (and *Hyallela azteca*) have been rated quite tolerant of certain natural phenomena (Table 2). *Hyallela azteca* has been rated pollution-tolerant, moderately tolerant, and indicative of very significant organic pollution (Table 2).

Order Isopoda (Aquatic sow bugs).—Most freshwater sow bugs are restricted to springs, spring brooks, streams, and interstitial and subterranean waters but some may be found in ponds and lake shallows (Pennak 1989). Sow bugs are scavengers, eating dead and injured aquatic animals and both green and decaying vegetation. They are eaten by fish and may be parasitized by roundworms and Acanthocephala.

Sow bugs were found only in the Lagoons reach (Fig. 1 and Table 1). *Caecidotea* (*Asellus*) was identified at both NPS1 and 2, and *Lirceus* was identified at NPS1. Like scuds, sow bugs generally require high dissolved oxygen concentrations and are usually limited to clean, cold waters (Covich & Thorp 1991). Sow bugs are especially sensitive to copper and a number of other heavy metals. The Family Asellidae, which includes *Caecidotea* and *Lirceus*, has been used as an indicator of severe organic pollution (Table 2). Asellidae and *Caecidotea* have been rated quite tolerant of certain natural phenomena (Table 2). *Caecidotea* has been rated pollution-tolerant and moderately tolerant, and *Lirceus* has been rated slightly tolerant (Table 2).

Order Decapoda (Crayfish).—The order Decapoda, which includes a great diversity of marine, freshwater, and semiterrestrial crustaceans, is represented in North American fresh waters by freshwater shrimp and crayfish (Hobbs 1991). The 386 described species and subspecies of crayfish in North America are assigned to 12 genera in two families (Astacidae and Cambaridae); only Cambaridae occurs in this area. Crayfish are common inhabitants of a wide variety of freshwater environments, including running waters, shallows of lakes, ponds, sloughs, swamps, subterranean waters, and even wet meadows (Pennak 1989).

Crayfish (Family Cambaridae) were identified at two sites, NPS1 in the Lagoons reach and FWS3 in the USX reach (Fig. 1 and Table 1). Those found at NPS1 were identified as *Orconectes*. Channelization and siltation can be very detrimental to crayfish populations (Hobbs & Hall 1974). Although crayfish concentrations may increase with limited organic enrichment, organic pollution resulting in oxygen depletion will result in smaller populations of fewer species. Crayfish are highly sensitive to an increase in acidity (Hobbs 1991). Crayfish have been rated quite tolerant of some pollution, and Cambaridae have been rated somewhat pollution-tolerant (Table 2).

Subphylum Chelicerata
Class Arachnida

Subclass Acari (water mites).—Water mites were found at NPS2 in the Lagoons reach (Fig. 1 and Table 1). They were not identified any further than Acari (formerly Acarina). Water mites are excellent indicators of environmental quality; their diversity is greatly reduced in chemically polluted or physically disturbed habitats (Smith & Cook 1991). Water mites have been rated as quite tolerant of certain natural phenomena and indicative of clean unpolluted waters (Table 2).

Subphylum Uniramia
Class Insecta (insects)

Order Ephemeroptera (mayflies).—The mayflies all have aquatic larvae that may be found in streams, rivers, lakes, and temporary or permanent ponds and marshes (Hilsenhoff 1991). Almost all mayfly larvae are herbivores or detritivores, but a few species prey on other invertebrates; the adults do not feed. Often, mayfly larvae are an important food source for fish in streams. The three families of Ephemeroptera were found in the Grand Calumet River: Baetidae, Caenidae, and Heptageniidae. All three families are recognized as indicators of clean, unpolluted waters (Hilsenhoff 1991). Baetidae are found in a variety of streams, ponds, and lakes; Caenidae are similarly widespread. Heptageniidae are characteristic of streams, waveswept shores, and temporary ponds; they typically cling to rocks, wood, or debris (Hilsenhoff 1991).

Mayflies were found at NPS1 and 2 in the Lagoons reach and IDEM8 in the Federal Dredging Project reach (Fig. 1 and Table 1). The Family Baetidae (small minnow mayflies) was represented by *Baetis* at NPS2 and IDEM8. The Family Caenidae (small squaregills) was represented by *Caenis* at NPS1 and 2. The Family Heptageniidae (flatheaded mayflies) was represented by *Stenonema* (*pulchellum* group) at IDEM8. Mayflies as a group are very important biological indicators for water quality because many species are very susceptible to water pollution or occur in predictable habitat types (McCafferty 1983).

Order Odonata (dragonflies & damselflies).—The odonates of North America are divided into two distinct suborders, Anisoptera (dragonflies) and Zygoptera (damselflies).

Dragonfly larvae were found at NPS1 and 2 in the Lagoons reach; FWS1, 3, 4, and 5 in the USX reach; and IDEM7 in the Lake George reach (Fig. 1 and Table 1). The Family Aeshnidae (darners) was collected at FWS1, 3, 4, and 5. The Family Corduliidae (green-eyed skimmers) was identified to *Neurocordulia* at NPS2 and *Tetragoneuria* at NPS1. The Family Libellulidae (common skimmers) was identified to *Erythemis* at IDEM7.

Most Aeshnidae larvae inhabit standing waters, especially weedy permanent ponds, marshes, and the shallows of lakes, and a few inhabit streams; Corduliidae also occupy stream debris, and Libellulidae are occasionally found along stream margins (Hilsenhoff 1991). Aeshnidae species have a wide range of tolerances (Illinois EPA 1985; Hilsenhoff 1987), and as a group they have been rated moderately tolerant of certain natural phenomena, indicative of clean unpolluted streams (Table 2). Corduliidae has been considered indicative of clean unpolluted streams and some probable organic pollution, and *Neurocordulia* has been rated slightly pollution tolerant (Table 2). Many species of Libellulidae are very adaptable and tolerant of low dissolved oxygen concentrations or highly eutrophic habitats (McCafferty 1983). Libellulidae has been considered indicative of both clean, unpolluted streams and likely severe organic pollution, and *Erythemis* has been rated moderately tolerant of certain natural phenomena, somewhat pollution tolerant, and characteristic of natural conditions (Table 2).

Damselfly larvae were found in the Lagoons, USX, Gary Sanitary District, DuPont, Roxanna Marsh, East Chicago Sanitary District, and Federal Dredging Project reaches (Fig. 1 and Table 1). Unidentified damselflies were found at IDEM2, 3, 4, 5, and 6. The Family Coenagrionidae (narrow-winged damselflies) was identified to family at FWS3, 4, and 5; *Argia* at IDEM1, 3, 4, 5, and 7; *Chromagrion* at NPS1 and 2; and *Ischnura* at NPS1 and 2 and IDEM1, 2, 3, 5, 7, and 8. The Family Lestidae (spread-winged damselflies) was identified at FWS5.

Damselflies, especially *Ischnura*, can generally tolerate a wide range of chemical conditions, including high organic loading (Roback 1974). Coenagrionidae larvae live mostly in permanent ponds, marshes, swamps, and lake shallows, and occasionally in parts of streams with little or no current; some *Argia* species inhabit riffles of streams (Hilsenhoff 1991). Lestidae larvae commonly inhabit vegetation in permanent and temporary ponds and marshes, and occasionally may be found among vegetation in slow streams (Hilsenhoff 1991). They have been rated quite tolerant of certain natural conditions, indicative of clean, unpolluted streams, and indicative of likely severe organic pollution (Table 2).

Order Trichoptera (caddisflies).—The larvae and pupae of all but one or two species of caddisflies are aquatic (Hilsenhoff 1991). More than 1340 species are known in North America. Caddisflies occur in most types of freshwater habitats, including spring streams and seepage areas, rivers, lakes, temporary pools, and marshes (Wiggins 1984). Most larvae consume plant materials in some form, including algae and decaying plant tissue, and some are mainly predacious. Caddisflies are an important part of the stream community and may dominate the insect biomass (Hilsenhoff 1991). Many fish species feed on the larvae and emerging adults.

Caddisflies were found at NPS1 and 2 in the Lagoons reach, TAMS2 and IDEM3 in the Gary Sanitary District and DuPont reaches, IDEM6 in the East Chicago Sanitary District reach, IDEM7 in the Lake George reach, and IDEM8 in the Federal Dredging Project reach (Fig. 1 and Table 1). The Hydropsychidae (common netspinners) were identified to family at IDEM8, *Cheumatopsyche* at IDEM6 and 8, *Hydropsyche* at TAMS2, *Hydropsyche orris* (uncertain) at IDEM8, and *Hydropsyche simulans* at IDEM3 (pupae) and IDEM8. The Hydroptilidae (micro caddisflies) were identified to *Neotrichia* and *Orthotrichia* at NPS1. The Leptoceridae (long-horned casemakers) were identified to *Anthripsodes*, *Leptocerus*, *Nectopsyche*, and *Oecetis* at NPS2. The Polycentropodidae (trumpetnet and tubemaking caddisflies) were identified to *Cyrnellus fraternus* at IDEM3 and 7, and *Neureclipsis* at IDEM6. Caddisflies are very important in biological monitoring, due to the wide variation in pollution tolerance among species (Hilsenhoff 1991).

Hydropsychidae larvae inhabit streams of all sizes, currents, and temperatures; and most are omnivores, feeding on algae, crustacea, and insects (Hilsenhoff 1991). They, like other net-builders, are generally tolerant of organic loading but not of toxic pollutants (Roback 1974). Hydropsychidae has been rated quite tolerant of certain natural phenomena, indicative of clean, unpolluted streams, and indicative of possible slight organic pollution (Table 2).

Hydroptilidae larvae may be found in a wide variety of habitats and feed on algae and other plant material (Hilsenhoff 1991). They have been rated quite tolerant of certain natural phenomena and indicative of possible slight organic pollution (Table 2).

Leptoceridae larvae occur in a variety of permanent aquatic habitats (Hilsenhoff 1991). Most are omnivore-detritivores, but *Oecetis* species are predators, and some *Ceraclea* feed on freshwater sponges (McCafferty 1983). They have been rated somewhat tolerant of certain natural phenomena, indicative of clean, unpolluted streams, and indicative of possible slight organic pollution (Table 2).

Most Polycentropodidae larvae inhabit streams, but they also occur in a variety of other habitats (Hilsenhoff 1991). Most species are predators, but a few are herbivores. Polycentropodidae has been considered moderately tolerant of certain natural phenomena, indicative of likely substantial organic pollution, and indicative of clean, unpolluted streams (Table 2).

Order Hemiptera (water bugs).—Water bugs are remarkably diverse and occupy many different habitat types, including saline ponds, mountain lakes, hot springs, and large rivers (Polhemus 1984). Most species are predators; however, many genera of the water boatmen (Corixidae) are primarily collectors, feeding on detritus. They can be important predators of mosquito larvae and adults; however, some species bite people or eat small fish in hatcheries, thereby becoming a nuisance. Most water bugs seem to be resistant to predation, possibly due to their characteristic scent glands. However, the water boatmen are preyed upon by fish and used as food for pet fish and turtles.

Water bugs were identified at NPS1 and 2 in the Lagoons reach and FWS5 in the USX reach (Fig. 1 and Table 1). The Family Belostomatidae was identified to *Lethocerus* at NPS2. The Family Corixidae was identified to family at FWS5 and *Sigara* at NPS1. The Family Pleidae (pygmy backswimmers) was identified to *Plea* at NPS2. Water bugs are more tolerant of environmental extremes than most insects, except the water beetles and flies (Roback 1974).

Giant water bugs inhabit permanent standing water habitats (*Belostoma* and *Lethocerus*), especially weedy ponds, lake margins, marshes, or streams (*Abedus*), among aquatic plants, or under rocks in riffles (Hilsenhoff 1991). Giant water bugs have been rated moderately tolerant of certain natural phenomena and indicative of clean, unpolluted streams (Table 2).

Water boatmen are good water quality indicators in standing waters (Polhemus 1984). They are found in most permanent aquatic habitats and frequently in temporary ones as well (Hilsenhoff 1991). *Sigara* are notable as herbivores (McCafferty 1983). Water boatmen have been rated quite tolerant of certain natural phenomena and indicative of clean, unpolluted streams, and *Sigara* has been rated quite tolerant of certain natural phenomena (Table 2).

Pygmy backswimmers inhabit vegetation, primarily in permanent ponds but also in lake shallows, stream backwaters, and swamps (Hilsenhoff 1991). They feed on small invertebrates. Pygmy backswimmers are considered indicative of clean unpolluted streams (Table 2).

Order Coleoptera (water beetles).—Water beetles were found at NPS2 in the Lagoons reach, IDEM1 in the USX reach, and IDEM6 in the East Chicago Sanitary District reach (Fig. 1 and Table 1). The Family Dytiscidae (predaceous diving beetles) was identified as *Dytiscus* at IDEM1 and *Laccophilus* at NPS2. The Family Gyrinidae (whirligig beetles) was identified as *Dineutus* at NPS2 and *Gyrinus* (uncertain) at IDEM6. The Family Haliplidae (crawling water beetles) was identified as *Haliplus* at NPS2. Water beetles are more tolerant of environmental extremes than most insects (Roback 1974). Both adults and larvae are predators, feeding primarily on other invertebrates and small vertebrates. They have been considered moderately tolerant of certain natural phenomena and indicative of clean, unpolluted streams (Table 2). *Dytiscus* has been considered moderately tolerant of certain natural phenomena, and *Laccophilus* has been considered pollution-tolerant (Table 2).

Whirligig beetles are widespread and often abundant (Hilsenhoff 1991). Larvae are predators, feeding mostly on other invertebrates; adults are scavengers on dead animals or predators of small invertebrates (White et al. 1984). They have been considered indicative of clean, unpolluted streams (Table 2). *Dineutus* has been considered slightly pollution-tolerant, and *Gyrinus* has been classified as pollution-tolerant (Table 2).

Crawling water beetles are often abundant in shallow, vegetation-choked habitats (Hilsenhoff 1991). Both larvae and adults are herbivores, feeding on algae or aquatic plants. They (and *Haliplus*) have been rated somewhat pollution-tolerant (Table 2).

Order Diptera (flies and midges).—*Biting midges (Family Ceratopogonidae):* Biting midge larvae live in a variety of aquatic habitats, including tree holes, marshes, swamps, ponds, lakes, and streams. Most larvae are carnivores, and others are herbivores or detritivores. Adults of some aquatic species feed on mammals; most others (including *Palpomyia*) feed on small insects (McCafferty 1983). Biting midges were found at NPS1 and 2 in the Lagoons reach, FWS5 in the USX reach, and IDEM6 in the East Chicago Sanitary District reach (Fig. 1 and Table 1). They were identified to family at FWS5 and IDEM6, and to *Palpomyia* at NPS1 and 2. *Palpomyia* has been considered moderately pollution-tolerant, indicative of likely substantial organic pollution, and pollution-tolerant (Table 2).

Phantom midges (Family Chaoboridae): Phantom midges, so called because of the near-transparency of their larvae, inhabit a wide variety of standing waters, including lakes, permanent ponds, spring ponds, temporary ponds, and swamp margins (Hilsenhoff 1991). The larvae prey on small animals such as insect larvae and crustaceans; adults do not feed. Phantom midges were identified as *Chaoborus* at IDEM2 in the USX reach and INHS1 in the Federal Dredging Project reach (Fig. 1 and Table 1). In different sources, they have been rated moderately pollution-tolerant and indicative of clean, unpolluted streams, and *Chaoborus* has been rated indicative of very significant organic pollution (Table 2).

Midges (Family Chironomidae): Larvae of the Family Chironomidae, by far the largest family of aquatic insects, inhabit all types of permanent and temporary aquatic habitats (Hilsenhoff 1991). They are found under a wider range of environmental conditions than any other group of aquatic insects and often occur in high densities and diversity (Coffman & Ferrington 1984). Midge larvae have a wide variety of feeding habits, with herbivore-detritivores and carnivores all commonly represented; adults do not feed (Hilsenhoff 1991). The larvae and adults are fundamental to the diets of many other aquatic invertebrates, fish, and birds (Williams & Feltmate 1992).

Midges were found at all sites except TAMS2 in the Gary Sanitary District and DuPont reaches and the INHS sites in the Federal Dredging Project reach (Fig. 1 and Table 1). There were unidentified midge larvae at all FWS sites and all IDEM sites. Pupae were found at IDEM2, 3, and 5. The Subfamily Chironominae tribe Chironomini was identified to: *Chironomus*, *Chironomus decorus*, *Dicrotendipes* (= *Limnochironomus*), *Dicrotendipes nervosus*, *Glyptotendipes*, *Microtendipes*, *Parachironomus*, *Parachironomus abortivus*, *Phaenopsectra*, *Polypedilum*, *Polypedilum convictum*, and *Stenochironomus*. The Subfamily Chironominae (Tribe Tanytarsini) was identified to *Cladotanytarsus* and *Rheotanytarsus*. The Subfamily Orthocladiinae was identified to: *Cricotopus*, *Cricotopus bicinctus*, *Cricotopus intersectus*, *Cricotopus sylvestris*, *Eukiefferiella*, and *Eukiefferiella discoloripes*. The Subfamily Tanypodinae was identified to: *Ablabesmyia*, *Labrundinia*, *Procladius sublettei*, and *Thienemannimyia* group. Midge larvae have been used as biological water quality indicators because different species or species groups may be associated with different pollutants or environmental conditions (Williams & Feltmate 1992). As a group, they have been rated quite tolerant of certain natural phenomena and indicative of likely substantial organic pollution if they are not blood-red or likely severe organic pollution if they are blood-red (Table 2).

The Subfamily Chironominae includes species with various tolerances to pollution (Illi-

Table 2.—Examples of tolerance ratings for macroinvertebrates collected in the Grand Calumet River. Ranges of tolerance: USDA (1989) = 2–108; Illinois EPA (1985) = 0–11; Chutter (1972) = 0–10; Hilsenhoff (1988) = 0–10; Hilsenhoff (1987) = 0–10; Patrick & Palavage (1994) = P(ollution tolerant) or N(atural conditions). * Value dependent on number of Baetid Ephemeroptera.

Taxa	USDA	Illinois EPA	Chutter	Hilsenhoff (1988)	Hilsenhoff (1987)	Patrick & Palavage
Phylum Porifera						
Phylum Cnidaria	108					
Hydridae						
Hydra			6			N
Phylum Platyhelminthes						
Turbellaria	108	6	3			
Phylum Nematoda	108		7			?
Phylum Bryozoa						
Plumatella						
Phylum Annelida						
Oligochaeta	108	10	8 or 10*			
Lumbricidae	108					
Lumbriculidae						
Tubificidae	108					
Limnodrilus						P
Limnodrilus cervix						P
Limnodrilus hoffmeisteri						P
Potamothrix vejdovskyi						
Quistadrilus multisetosus						
Hirudinea	108	8	7			
Erpobdellidae		8				
Dina microstoma?						
Dina parva						P
Erpobdella punctata						P
Mooreobdella						
Mooreobdella fervida						
Mooreobdella microstoma						
Glossiphoniidae		8				
Helobdella						
Helobdella stagnalis						P

Table 2.—Continued.

Taxa	USDA	Illinois EPA	Chutter	Hilsenhoff (1988)	Hilsenhoff (1987)	Patrick & Palavage
Placobdella						
Phylum Mollusca						
Gastropoda	108		0			
Ancylidae			4			
Ferrissia		7				P
Hydrobiidae						
Amnicola		4				
Lymnaeidae	108					
Lymnaea	108	7				
Physidae	108					
Aplexa		7				
Physa	108	9				P
Physella						
Planorbidae	108					
Gyraulus		6				
Helisoma		7				P
Planorbula		7				
Promenetus						
Promenetus?						
Valvatidae						
Valvata		2				N
Bivalvia/Pelecypoda	108		0			
Corbiculidae		4				
Dreissenidae						
Sphaeriidae (unident.)						
Pisidium		5				P
Sphaerium		5				P
Phylum Arthropoda						
Branchiopoda						
"Cladocera"	108					
Amphipoda	108		0			
Hyalella	108	6			8	P
Isopoda	108		0			
Asellidae	108					

Table 2.—Continued.

Taxa	USDA	Illinois EPA	Chutter	Hilsenhoff (1988)	Hilsenhoff (1987)	Patrick & Palavage
Caecidotea/Asellus	108	6				P
Lirceus		4				
Decapoda	108		0			
Cambaridae	108	5				
Orconectes						
Arachnida						
Acari	108		0			
Insecta						
Ephemeroptera	72					
Baetidae	72		0	4		
Baetis	72	4				N
Caenidae	72		1	7		
Caenis	72	6			7	N
Heptageniidae	48		0	4		
Stenonema (*pulchellum* group)	48	3			3	N
Odonata, Anisoptera			0			
Aeshnidae	72			3		
Corduliidae				5		
Neurocordulia		3				
Tetragoneuria						
Libellulidae	72			9		
Erythemis	72	5				N
Odonata, Zygoptera			0			
Coenagrionidae	108			9		
Argia	108	5				N
Chromagrion						
Ischnura	72	6				
Lestidae	108			9		
Trichoptera			0			
Hydropsychidae	108			4		
Cheumatopsyche	108	6			5	N
Hydropsyche	108	5				N
Hydropsyche orris?		4			5	N
Hydropsyche simulans		5			7	

Table 2.—Continued.

Taxa	USDA	Illinois EPA	Chutter	Hilsenhoff (1988)	Hilsenhoff (1987)	Patrick & Palavage
Hydroptilidae	108			4		
Neotrichia	108	4			2	N
Orthotrichia		1	2			
Leptoceridae	54			4		
Anthripsodes						
Leptocerus		3				
Nectopsyche		3			3	N
Oecetis	54	5			8	N
Polycentropodidae	72			6		
Cyrnellus fraternus		5			8	
Neureclipsis		3			7	N
Hemiptera			0			
Belostomatidae	72					
Lethocerus	72					
Corixidae	108					
Sigara	108					
Pleidae						
Plea						
Coleoptera			0			
Dytiscidae	72					
Dytiscus	72					P
Laccophilus	72					
Gyrinidae	108					
Dineutus		4				
Gyrinus?	108	4				
Haliplidae	54					
Haliplus	54					
Diptera						
Ceratopogonidae	108	5	0	6		
Palpomyia		6			6	P
Chaoboridae		8	0			
Chaoborus					8	
Chironomidae	108			6 or 8 (red)		

Table 2.—Continued.

Taxa	USDA	Illinois EPA	Chutter	Hilsenhoff (1988)	Hilsenhoff (1987)	Patrick & Palavage
Chironominae						
(Chironomini)			7*			
Chironomus		11	10		10	P
Chironomus decorus						P
Dicrotendipes/Limnochironomus		6			8	N
Dicrotendipes nervosus		6				N
Glyptotendipes		10			10	
Microtendipes		6			6	
Parachironomus		8			10	P
Parachironomus abortivus						
Phaenopsectra		4			7	
Polypedilum		6			6	P
Polypedilum convictum						P
Stenochironomus		3			5	N
(Tanytarsini)			0			
Cladotanytarsus		7			7	P
Rheotanytarsus		6			6	P
(Orthocladiinae)			7*			
Cricotopus		8			7	
Cricotopus bicinctus		10				P
Cricotopus intersectus						
Cricotopus sylvestris						
Eukiefferiella		4			8	N
Eukiefferiella discoloripes						
(Tanypodinae)			0			
Ablabesmyia		6			8	P
Labrundinia		4			7	
Procladius sublettei		8			9	N
Thienemannimyia group		6				N
Culicidae	108	8	10			
Tipulidae	72	4	0	3		
Empididae	108	6	0	6		
Stratiomyidae	108		0			
Syrphidae	108	11	0	10		

nois EPA 1985; Hilsenhoff 1987). Of the Chironomini genera found in these studies, *Chironomus* has been rated the most tolerant and *Stenochironomus* the least (Table 2). The tribe Tanytarsini has been used to indicate clean, unpolluted waters (Table 2). *Cladotanytarsus* has been rated moderately pollution-tolerant, indicative of significant organic pollution, and pollution-tolerant (Table 2). *Rheotanytarsus* has been rated moderately pollution tolerant, indicative of fairly significant organic pollution, and pollution-tolerant (Table 2).

The Subfamily Orthocladiinae contains species with a wide range of pollution tolerances (Illinois EPA 1985; Hilsenhoff 1987). It has been given a sliding scale of tolerance values by Chutter (1972) with the values dependent on the diversity and abundance of Baetid mayflies; in these studies, the subfamily indicates organically-enriched to polluted waters. *Cricotopus* has been rated moderately pollution-tolerant and indicative of significant organic pollution, and *Cricotopus bicinctus* has been rated very pollution-tolerant, indicative of severe organic pollution, and pollution-tolerant (Table 2). *Eukiefferiella* has been rated slightly pollution-tolerant, indicative of very significant organic pollution (Table 2).

The Subfamily Tanypodinae also contains species with a wide range of tolerances (Illinois EPA 1985; Hilsenhoff 1987). It is considered indicative of clean unpolluted streams (Table 2). *Ablabesmyia* has been rated moderately pollution-tolerant, indicative of very significant organic pollution, and pollution-tolerant (Table 2). *Labrundinia* has been rated slightly pollution-tolerant and indicative of significant organic pollution (Table 2). *Procladius* has been rated moderately pollution-tolerant, indicative of severe organic pollution (Table 2). *Thienemannimyia* group has been rated moderately pollution-tolerant and characteristic of natural conditions (Table 2).

Mosquitoes (Family Culicidae): Mosquito larvae were identified at IDEM6 in the East Chicago Sanitary District reach (Fig. 1 and Table 1). Mosquito larvae have been rated quite tolerant of certain natural phenomena, moderately pollution-tolerant, and indicative of organically-polluted streams (Table 2).

Crane flies (Family Tipulidae): Crane fly larvae were common at IDEM6 in the East Chicago Sanitary District reach (Fig. 1 and Table 1). Crane fly larvae have been rated moderately tolerant of certain natural phenomena, slightly pollution-tolerant, indicative of unlikely organic pollution and of clean unpolluted waters (Table 2).

Dance flies (Family Empididae): One dance fly larva was found at FWS5 in the USX reach (Fig. 1 and Table 1). It was identified only to family. Dance fly larvae have been rated quite tolerant of certain natural phenomena, moderately pollution-tolerant, indicative of likely substantial organic pollution, and indicative of clean, unpolluted streams (Table 2).

Soldier flies (Family Stratiomyidae): Soldier fly larvae were identified at FWS4 in the USX reach (Fig. 1 and Table 1). They were not identified beyond family. Soldier fly larvae have been considered quite tolerant of certain natural phenomena, indicative of clean, unpolluted streams, and pollution-tolerant (Table 2).

Rat-tailed maggots/flower flies (Family Syrphidae): Rat-tailed maggots inhabit shallow standing waters or margins of running waters, especially areas high in decomposing organic matter (Hilsenhoff 1991). Because of their very long breathing tube, rat-tailed maggots are able to inhabit very polluted, low-oxygen areas such as sewage lagoons. Rat-tailed maggots were found at FWS4 in the USX reach (Fig. 1 and Table 1). Rat-tailed maggots have been rated as very pollution-tolerant, indicative of likely severe organic pollution (Table 2).

SUMMARY AND RESTORATION POSSIBILITIES

Current macroinvertebrate habitats in the Grand Calumet River and Indiana Harbor Canal are degraded, as is evident by the resident communities. In all reaches other than the Lagoons reach, aquatic earthworms and other pollution-tolerant organisms are dominant, and the more sensitive taxa are either scarce or non-existent, which suggests a highly degraded habitat (Tables 1, 2). The Lagoons reach appears to be less affected, probably because the lagoons are located above industrial and sanitary outfalls (IDEM 1991). This reach is somewhat degraded, however, particularly the West Lagoon where the macroinvertebrate community appears to be stressed by extremely high ammonia levels (Hardy 1984).

So many changes have occurred over the Grand Calumet River's history that it may be nearly impossible for it to return to its presettlement state. However, there are several ways to improve the river's habitat quality and bring back a healthier and more diverse macroinvertebrate population. Different approaches for restoring the various reaches will depend primarily on reach-specific factors other than macroinvertebrate community composition.

In-place sediment clean-up.—First, the problem of contaminated sediments must be addressed. Grand Calumet River and Indiana Harbor Canal sediments are known to be contaminated by a wide variety of pollutants, including nutrients, organic matter, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and high concentrations of metals (USACE 1994a). Contaminated sediment can impact macroinvertebrates in a number of ways—directly, as a living and foraging area and food source, and indirectly, as a source of water and prey contamination and oxygen depletion. Improving sediment quality will be necessary to restore macroinvertebrate habitat in the Grand Calumet River, and one way to achieve this is by cleaning up the contaminated sediments.

Sediment clean-up options include removal (dredging), capping with clean materials, and in-place treatment. Although it is theoretically feasible, not enough is known about in-place treatment (e.g., fixation/solidification or biodegradation) to consider it seriously at this point (USACE 1994a). Dredging—the excavation of bottom sediments from a waterway—may be performed with a variety of equipment (USACE 1994b). The two basic types of dredges are mechanical dredges, which remove sediments using a large bucket or shovel, and hydraulic dredges, which remove and transport the sediments in water slurry. The particular method selected depends on reach-specific factors that will not be discussed here.

The positive impacts of dredging on the aquatic macroinvertebrates, provided that it would remove the total depth of contaminated sediments, would be the removal of the contaminants (and thus their direct and indirect negative impacts) from the system, and the uncovering of uncontaminated sediments for recolonization. However, both of these benefits would be greatly reduced without sediment source controls (see below). Removing only part of the contaminated sediments would be of little benefit unless water depth was maintained with capping.

The negative impacts of dredging would include the removal of existing benthic macroinvertebrates and rooted vegetation, changes in channel morphology, and temporary, localized degradation of water and habitat quality. Although little can be done about removing the benthic community, it is a degraded community. Further, the newly exposed-sediments would be recolonized and revegetated over time. The other negative impacts could be minimized by taking certain steps during and after dredging. The placement of weirs up- and downstream of the dredging operation would help maintain water flow and surface levels and could localize turbidity during dredging. Digging the channel too deep or the banks too steep would encourage the re-establishment of rooted vegetation and minimize flow pattern changes and riverbank sloughing. In reaches where the contaminated sediment is quite deep or the river is already too channeled, the bottom could be filled with clean sediment.

Capping is the covering of contaminated sediment by clean materials (USACE 1994a). The contamination remains in the waterway, but its availability to the water column and aquatic life is reduced. The cap must isolate sediment contamination from the overlying water, prevent penetration by benthic or burrowing organisms, and be resistant to scour. Cap design depends on various factors, including the hydraulic system, sediment characteristics, and types of contamination. One concern with leaving the sediment in place is that groundwater may still interact with the contaminants.

The positive impacts of capping on the aquatic macroinvertebrates, provided that it would isolate and stabilize the contaminated sediments, would be the removal of the possibility of direct and indirect negative impacts from the contaminants and the availability of new, uncontaminated sediments for recolonization. However, both of these benefits would be greatly reduced without sediment source controls.

The negative impacts of capping would include the covering of existing benthic macroinvertebrates and rooted vegetation and possible adverse habitat impacts due to water depth reduction in shallow areas. Although little could be done about the first impact, the macroinvertebrate communities that would be buried are degraded, and the newly-exposed sediments would be recolonized and revegetated over time. In shallow areas, partial dredging prior to capping could compensate for water depth loss.

Sediment source controls.—Source controls, which reduce the quantity and contamination level of sediments entering the river, will be very important in improving sediment quality and macroinvertebrate habitat in the Grand Calumet River and Indiana Harbor Canal. If done properly, they may only impact the macroinvertebrate communities positively. Reductions in the quantity of sediment entering the river would improve habitat by decreasing siltation and turbidity, both of which can be detrimental to some macroinvertebrates. Without reductions in contamination levels of sediments entering the river, sediment clean-up would only provide a temporary solution, since uncontaminated sediment would simply be covered and replaced by more contaminated sediment (USACE 1994a).

There are three major sources of sediments to the Grand Calumet River and Indiana Harbor Canal: municipal and industrial point discharges, combined sewer overflows (CSOs), and urban runoff. Point sources include three municipal wastewater treatment plants and over 40 outfalls for discharges from industries and manufacturers. Over 90% of the system's dry-weather flow originates as treated municipal and industrial wastewater (McCown et al. 1976). Point discharges are regulated under the Clean Water Act (NPDES permit program); effects of this regulation can be seen in the 56% reduction of suspended solids loadings from point sources between 1974–1984 (USACE 1994a). The Remedial Action Plan (RAP) calls for full compliance of all NPDES discharges and the resolution of enforcement actions against violators (IDEM 1991).

Combined sewer overflows are not as easily controlled as point discharges (USACE 1994a). CSOs result from heavy rainfall events increasing flow in a combined sewer system so that it exceeds the capacity of the sewer or the wastewater treatment plant. This causes a mixture of stormwater and raw sewage to be discharged directly to the river. Possible solutions to CSOs include separating sewers into sanitary and storm sewers and constructing a detention basin or tunnel for temporary storage of combined sewer flows during storms for later treatment and discharge. The NPDES permits with the sanitary districts of East Chicago, Hammond, and Gary would have to be modified by IDEM to require satisfactory maintenance and operation of the combined sewer systems.

Urban runoff is the most difficult source to control (USACE 1994a). Approximately 47% of the Grand Calumet River watershed east of the Illinois/Indiana border is occupied by heavy industry, while only 7.6% is open space (Ketcham et al. 1992). Measures for controlling the amount of sediment released into the river in stormwater (other than making large changes to the existing land-use practices) include detention basins, retention devices, constructed wetlands, vegetative controls, construction erosion controls, and source controls (e.g., street sweeping and protection of stockpiled materials from rainfall).

Sediment transport controls.—Transport controls reduce the resuspension and transport of sediments that have already been deposited on the river bottom. Reductions in sediment resuspension and transport would improve macroinvertebrate habitat by reducing turbidity, erosion, and the exposure of the organisms and the water column to sediment contaminants (USACE 1994a). Sediment impacts on water quality and aquatic organisms are directly related to the sediment surface area exposed; and when sediments are in suspension, surface area is greatly increased. Sediment resuspension could be reduced by changing the hydrology and hydraulics of the river and canal or by controlling physical disturbances that cause resuspension, such as boat traffic and dredging.

Due to the effects of urbanization on the Grand Calumet River watershed, stormwater flows in the river can be much greater than normal flows, resulting in scouring and resuspension of sediments. In addition to the other ecological problems created by these high flows, they could make capping of contaminated sediment more difficult or infeasible, since the capping material may be washed downstream (USACE 1994a). Many of the same methods mentioned above for decreasing sediments in urban runoff and CSOs would also reduce peak storm flows.

Another method that has been used to control sediment transport is a sediment trap or settling basin (USACE 1994a). A deepened channel or basin is excavated within a waterway to catch sediments from upstream, and the sediments are then dredged and disposed nearby. This practice is useful for preventing deposition in a high quality reach, and it is more cost-effective than removing sediments from a long stretch of river.

Water quality improvement.—Historically, the Grand Calumet River and Indiana Harbor Canal have been plagued with water quality problems, including low oxygen levels and high levels of ammonia, total dissolved solids, total phosphorus, chlorides, fluorides, sulfates, oil and grease, bacteria, cyanide, metals, and PCBs (IDEM 1991). Although most of these parameters have improved, many still exceed applicable water quality standards. Improving the water quality of the waterway would also better the health of its macroinvertebrate community.

The sources of water pollution to the Grand Calumet River and Indiana Harbor Canal include municipal and industrial point discharges, CSOs, urban runoff, air deposition, groundwater contamination, and contaminated sediments (IDEM 1991; USACE 1994a). The first three of these are also major sediment sources and are described more fully in the previous section. The NPDES permit program regulates pollutants in point discharges. In general, methods used to decrease the quantity and contamination level of sediments entering the river from CSOs and urban runoff would also decrease the input of other water-borne contaminants.

Air deposition includes both wet deposition, which is precipitation of any type, and dry deposition, which is the settling of dry particles from the air. Because the area is highly industrialized, air deposition may be an important source of contaminants to the Grand Calumet River and Indiana Harbor Canal. Northwest Indiana has the highest levels of precipitation-borne lead in the Great Lakes region (Gatz et al. 1989), and Indiana Dunes National Lakeshore has the highest levels of precipitational sulfate and nitrate of any monitored national park unit in the country (NADP 1993). Both direct and indirect deposition to the river and canal could be decreased through better emissions controls, and indirect deposition could be decreased by many of the same methods used for decreasing sediment levels in urban runoff and CSOs.

Groundwater contamination may be another source of water pollution to the Grand Calumet River and Indiana Harbor Canal. Analysis of water samples taken from 128 wells in the Calumet Region indicated that groundwater quality has changed in parts of the study area as a result of industrialization and urbanization (Duwelius et al. 1996). The largest concentrations of trace elements and organic compounds were detected in samples from wells located in or near industrial areas or areas of waste disposal. A total of 14 volatile organic compounds, 23 semivolatile organic compounds, and 18 pesticide compounds were detected in 20, 56, and 29 of the samples, respectively. Compounds containing PCBs were detected in water from three of the wells.

Contaminated sediments can have a significant impact on water quality by acting as a source for nutrients and contaminants and as a sink for dissolved oxygen (USACE 1994a). Brannon et al. (1989) found that the overall transport and migration of sediment contamination in the Grand Calumet River and Indiana Harbor Canal was influenced by the following factors in descending order of importance: transport of contaminants associated with particulates, transport of contaminants desorbed from resuspended particulates, and transport of soluble contaminants released from deposited sediment. Release of contaminants from deposited sediment is the least important factor because sediments have a much greater exposed surface area when suspended, and the exposed surface area directly affects the release of contaminants, as well as the release of nutrients and the rate of oxygen demand (USACE 1994a). In-place sediment clean-up, sediment source controls, and sediment transport controls would all help to improve the water quality of the Grand Calumet River and Indiana Harbor Canal.

The river corridor.—Restoration of the Grand Calumet River and its macroinvertebrate populations must involve more than the river itself. The river is just one part of the larger ecosystem, and its health is related to the health of all other parts. There are several important natural habitat areas along the river corridor, such as Miller Woods in the Lagoons reach and Clark and Pine East Nature Preserve in the USX reach, that need to be preserved and protected. Wetlands and riparian areas need to be restored and protected wherever possible. The impacts of restoration alternatives, particularly sediment clean-up options, must be considered for the whole system rather than for the river alone. In some areas, such as the East Lagoon, it may be preferable to leave the contaminated sediments in place rather than risk damaging the surrounding natural area with dredging and disposal activities.

The challenge.—The greatest challenge will be to restore the Grand Calumet River and Indiana Harbor Canal to their best possible ecological health given the various social, economical, and political constraints. Restoration would require the cooperation of federal and state agencies, local governments, industries, municipal wastewater treatment plants, and the public; and many compromises would be necessary. Industrial and residential development have severely altered the landscape and the river itself, yet there remains a great potential for improving the health of the river and the whole ecosystem.

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In addition to transportation crossings, the areas around the Grand Calumet River are heavily used by industry. Pipelines run along much of its length and across the channel. The banks have been heavily modified in order to maintain industrial equipment.

Gradually sloping banks have been sharply inclined along much of the river where the bank has been cut back to widen the channel and protect industrial pipelines. This greatly impacts drainage and natural vegetation.